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Spatial Analysis of the Distribution of Specialist Physicians' Offices in Mashhad

A pattern of inverse spatial diffusion

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Abstract: The spatial diffusion theory and its patterns (expansion, hierarchical, contagious, and relocation) explain how phenomena disseminate from the origin of diffusion. By investigating the spatial pattern of specialist physicians' offices in the city of Mashhad, the present study showed that, contrary to common patterns, a new pattern of spatial diffusion was formed by increasing the number of phenomena but not diffusing them at the origin. This was a descriptive-analytical study and the sample included all specialist physicians' offices in Mashhad (including 27 specialist physicians and 2425 offices). To this end, a geographic database of specialist physicians' offices was created according to their type of specialty and addresses. Then, the diffusion pattern and origin of the offices were identified using spatial analysis models such as density profiles, mean center, and standard distance. Then, it was examined how each office diffused according to the type of specialty using spatial autocorrelation models, network analysis, and location-allocation. Finally, the diffusion rate of each specialty was determined using scatter diagrams and correlation coefficient. The results indicated that the distribution of offices in the city of Mashhad follows a new pattern called "inverse spatial diffusion". It is characterized by high mobility of phenomena at the origin, a high correlation between the number of offices in each specialty and their absorption rates, and non-diffusion of offices at the origin. This was resulted in high daily inflows and outflows of people to this area, low diversity of land uses, and isolation of this area from other parts of the city.

1. INTRODUCTION

Movement represents the evolution process of phenomena and is one of the most important issues in human life and among various sciences (Arabi, 1992). In geography, the category of movement has a practical and specialized aspect and refers to the process of evolution and change of spatial phenomena over time. In this view, time, space and movement are among the important dimensions of spreading phenomena in space. Moreover, the logic of positioning them in space serves as a measure for thinking about events and their extension. Although some believe in the death of distance (Merriman, 2012), physical proximity is still an important

factor in shaping social ties in virtual social networks (Lengyel and Jakobi, 2015). As a geographical phenomenon expands spatially and temporally, a spatial pattern can be seen at each time stage (Lee, Lay, Chin, Chi, and Hsueh, 2014). In this regard, many theories have been developed over time. One of the most important is the "spatial diffusion theory". The theory is related to temporal-spatial models, spatial flows, and spatial changes (Casetti, 2001) and shows the movement process of phenomena including humans and goods across different regions over time. This theory has four patterns: 1) Expansion 2) Relocation 3) Contagious and 4) Hierarchical diffusion (Janelle, 2003).

A closer examination of the spatial diffusion patterns reveals two major challenges: First, diffusion patterns have not developed over time, and the original four patterns are still mentioned in the literatures. Second, these patterns show how phenomena diffuse from the origin to the surroundings. In other words, In the patterns of spatial diffusion theory, it is assumed that the phenomenon spreads from the origin. And this is part of the life cycle of the phenomenon. Therefore, if the diffusion does not occur from the origin, it is assumed that the phenomenon has disappeared or stagnated before reaching the diffusion stage.

Therefore, it is natural that the current patterns can't evaluate the changes if the diffusion does not occur from the origin, so they can indicate a stagnation of the respective phenomenon. However, if the volume or the number of phenomena at the origin is increasing, the assumption of stagnation should probably be rejected. In such a situation, a question arises that what pattern can evaluate this issue?

The city of Mashhad, as a study area, well exemplifies the challenge and there may be rare similar cases. Mashhad located in northeastern Iran and the capital of Khorasan Razavi province. Mashhad, Iran's holiest and second-largest city, with a population of 3 million (Statistical Center of Iran, 2016) and a 1000-year-old history (Housing and Urban Development Organization of Khorasan Province, 1968), reflects different physical, demographic, and economic landscapes (Shahnoshi, 2007). Having established Imam Reza and Ghaem hospitals next to each other during the years 1935-1961, the primary core was gradually formed for the deployment of specialist physicians' offices. Since then, this area has not only maintained its role, but also the number of specialist physicians' offices in this area has increased. For example, in 2010 the number of specialist physicians' offices in the city was 541, which increased to 2425 offices (growth rate of 448%) in 2020. Therefore, it seems that due to the developments in this nucleus, there is no sign of the diffusion of offices from the origin to the outside. This has some impacts on the access of 3 million people living in the city to such services and challenges the way in which spatial diffusion patterns are encountered. Therefore, given to the distribution of specialist physicians' offices in Mashhad, this study seeks to show the way of diffusion in this area according to the spatial diffusion theory using spatial analysis methods and statistical models. It also intends to suggest a new diffusion pattern in order to introduce developments at the origin of diffusion.

This issue has theoretical as well as practical dimensions as the establishment and distribution of medical uses is a necessary and binding strategy to promote public health and is widely considered as a global solution to improve the quality of life for all people (Holt, 2005). Public health is affected by the access to such services. In this regard, several studies show that as travel time to clinic increases, there is a significant decline in the usage of medical services (Frank, 2006). In other words,

deprivation and lack of access to health care services may lead to higher mortality rate (Ajala, 2005).

Spatial diffusion was first raised by Hagerstrand in his book "Innovation Diffusion as a Spatial Process" in 1953 in Sweden (Haggett, 1996) and now is considered as one of the ways of analysing displacements (people, goods, styles, etc.) in urban areas. However, it can also be traced in the theories of Chicago school researchers. Ernest Burgess (1886-1966), for example, suggested that in the physical development of a city, the process of dispersing land uses takes place, and consequently, individuals and groups disperse (Poorahmad and Shamaeipour, 2001). Homer Hoyt (1933) believed that economic and social differences in demographic and physical structure caused segmental shape of the city (Farid, 2012). According to Calvin Schmid, social changes in urban texture occur due to their development (Shokui, 1994). Peter Haggett didn't consider this "diffusion" as a mere shift. Rather, it is a valuable key to know how information is exchanged between regions (Haggett, 1996).

In general, spatial diffusion are classified into four patterns (Cliff, Hagget, Ord, and Versey, 1981): 1) Expansion diffusion: Leakage from the source to the surrounding areas so its range is expanded. That is, between two time periods, new areas are added. 2) Relocation diffusion: leakage from the source and is accompanied by displacement, such as migration from rural to urban areas. 3) Contagious diffusion: a type of diffusion that is spatially interconnected; and 4) hierarchical diffusion: as the prevalence of fashion types that occur without being affected by the places between the source and destination (*Figure 1*).

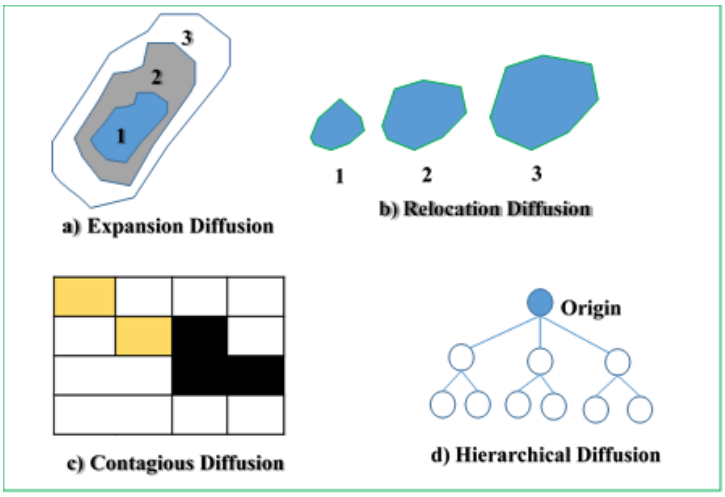

Figure 1. Spatial diffusion patterns (1,2,3 are stages of diffusion)

Having reviewed the studies conducted in this field, it was revealed the important position and capability of the spatial diffusion theory in different issues such as, the spread of innovation and technology (Smith and Song, 2010; Feola and Butt, 2015; Tonis, Yarwood, and Jones, 2010; Lengyel, Bokányi, and Di Clemente, 2020; Comin, Dmitriev, and Ross, 2012), analysis of economic characteristics and taxes (Beckmann, 1970; Hall, Lacombe, and Tackett, 2020), religion (Land, Deane, and Blau, 1991), rural development (Kim and Chung, 2005), online social networks (Lengyel and Jakobi, 2015), social movements (Miller, 2001), the development of new family spatial patterns (Caltabiano, Dreassi, Rocco, and Vignoli, 2019), spatial analysis of mortality rates (Fricks and Hanks, 2018), political spatial

developments (Goodchild, 2001; Mitchell, 2017), third places (Liefooghe, 2018), diseases (Golub, Gorr, and Gould, 1993; Bowen and Christian, 2006), land use (Brown, Rounsevell, and Alexander, 2018; Wei , Yue, Yanan , and Qun, 2018; Brady, 2014) etc.

Studies show that spatial diffusion has shifted from focusing on a particular model-Hagerstrand- to a fundamental theme and modeling interest in geography (Morrill, Gaile, and Thrall, 1988). In recent years, there have been some efforts to incorporate spatial statistics to better distinguish and detect spatial diffusion processes (Lee, Lay, Chin, Chi, and Hsueh, 2014) as the spread of people, goods, information, and ideas can be sometimes more complex than what a diffusion diagram can describe. This is due to the way such things are transmitted is no longer limited to a local geography or through a limited network of contacts. Hence, studies of spatial diffusion and its processes are more complex and specialized than traditional approaches (Lee, Lay, Chin, Chi, and Hsueh, 2014).

The studies performed on the spatial diffusion theory and its patterns, irrespective of the subject under study, can be classified into three categories:

1. Studies based on spatial diffusion model regardless of diffusion patterns (Lengyel, Bokányi, and Di Clemente, 2020; Mitchell, 2017; Comin, Dmitriev, and Ross, 2012; Caltabiano, Dreassi, Rocco, and Vignoli, 2019; Liefooghe, 2018; Miller, 2001; Fricks and Hanks, 2018).

2. Studies that have tried to implement the spatial diffusion theory using various methods such as relocation (Beckmann, 1970), spatial autocorrelation (Lam, Fan, and Liu, 1996; Hall, Lacombe, and Tackett, 2020), box-counting (Knoke, 1982), spatial regression (Brady, 2014; Wei , Yue, Yanan , and Qun, 2018), the combination of spatial statistics including Nearest Neighbor Analysis and Regression Estimation (Lee, Lay, Chin, Chi, and Hsueh, 2014), statistical models (Brady, 2014), and logistic models (Brown, Rounsevell, and Alexander, 2018).

3. Finally, studies that examined the spatial variations of phenomena using spatial diffusion patterns (quadruple patterns), without developing a new pattern (Knoke, 1982; Thierry, Rizz, and Doignon, 2020; Yuming, 2004; Brown, Rounsevell, and Alexander, 2018).

2. MATERIALS AND METHODS

2.1 Study process

The study of spatial diffusion patterns is not possible without referring to spatial analysis methods and statistical methods. A subject that confirms it well, in previous studies. In this study, the process of using statistical methods and spatial analysis is specified in study process (figure 1). It has been tried that this process can show step by step: 1) the evolution of the phenomenon in the origin, 2) the spatial relationships among different specialist physicians, and 3) the general pattern governing them.

In sum, the data of 2425 offices in Mashhad was entered into the database. The data of specialist doctors' offices were obtained from the website of the Medical System Organization of Mashhad in 2020. We created a table of raw data related to each of the specialist doctors' offices in Mashhad. In this table, 1) the address, 2) type of specialization and 3) time

of establishment, were specified. Then we entered this table in the geodatabase in ArcMap software.

Data analysis was performed at both local and global levels. At the local level the trends of spatial positions and spatial differences between the origin and surroundings are identified. At the global level the general diffusion pattern is identified. These two levels were performed in the following three steps (*Figure 2*).

1) Using mean center models, standard distance, spatial autocorrelation, and density profiles, the spatial diffusion of the offices in the origin and surroundings (irrespective of the type of specialty) and the existing differences were identified.

2) Using local models such as Moran, network analysis and location-allocation model, the diffusion of offices for each specialty in Mashhad especially in the origin was examined. The results specified the pattern governing the distribution of each specialty, clustering rate, functional radius of each office, the overlapping amount as well as the coverage potential of offices and the gap with the status quo.

3) Using Global statistical models such as correlation and by employing scatter diagrams, the general pattern governing the offices was obtained. Research variables are the absolute and relative positions of specialist physicians' offices, their type of specialty and their history.

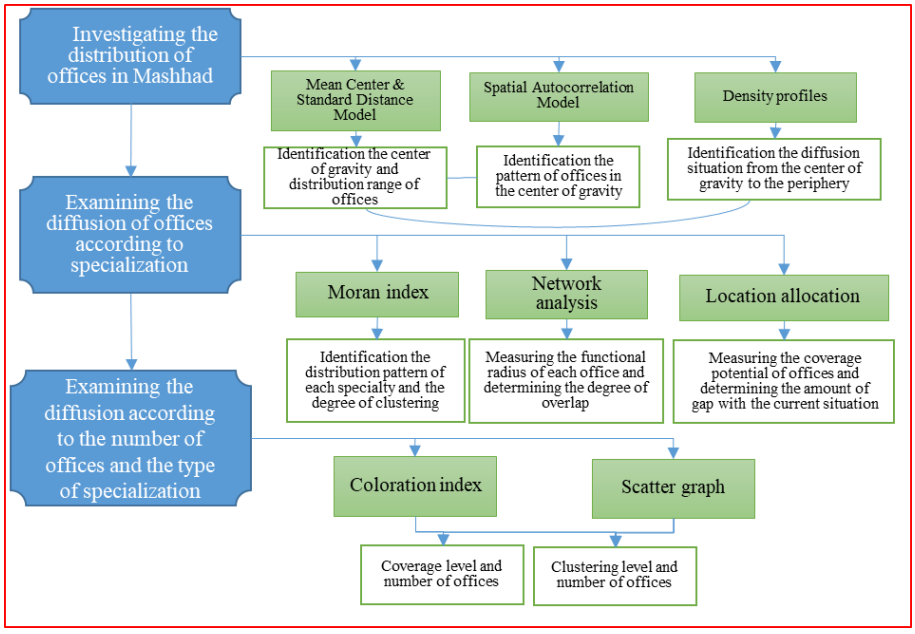

Figure 2. Study process

In this study, while paying attention to the correct application of the use of models and meeting the prerequisites for input data, the most important criterion for confirming the process was the fidelity of the analysis process to the problem and the main goal of the study. In other words, what models and methods can measure the main question and problem of the research (spatial distribution and diffusion of specialist doctors in Mashhad)? The models that have been developed in the world literature in this regard are well known. In the analysis process, in addition to the above topics, attention to previous studies (which are mentioned in the theoretical literature), as well as the author's experiences in the field of using spatial analysis methods in various studies have also been the criteria of action.

2.2 Study area

The study area is the city of Mashhad and the specialist physicians' offices in it. To this end, a list of specialist physicians of Mashhad was prepared referring to the Mashhad Medical Council, and according to each office address, their spatial locations were specified in a geographic database in ArcGIS. The type of specialty was also determined in the database (*Figure 3*).

Figure 3. Geographical location of Mashhad in Iran and Razavi Khorasan province

3. FINDINGS

3.1 Categories

According to the available information, there are 2425 specialist physicians' offices in 27 types of specialties in Mashhad. According to the frequency of each specialty, they can be classified into 4 categories (*Figure 4*):

Category 1: gynecology, pediatrics and gastroenterology specialties (with an average of 282 offices per specialty).

Category 2: specialties of heart, anesthesia, radiology, eye, brain, orthopedics and ear (with an average of 129 offices per specialty).

Category 3: specialties of psychiatry, surgery, pathology, dermatology, urology, and infectious diseases (with an average of 77 offices per specialty).

Category 4: radiotherapy, emergency, laboratory, physiotherapy, nutrition, lung, endocrinology, acupuncture (with an average of 19 offices per specialty).

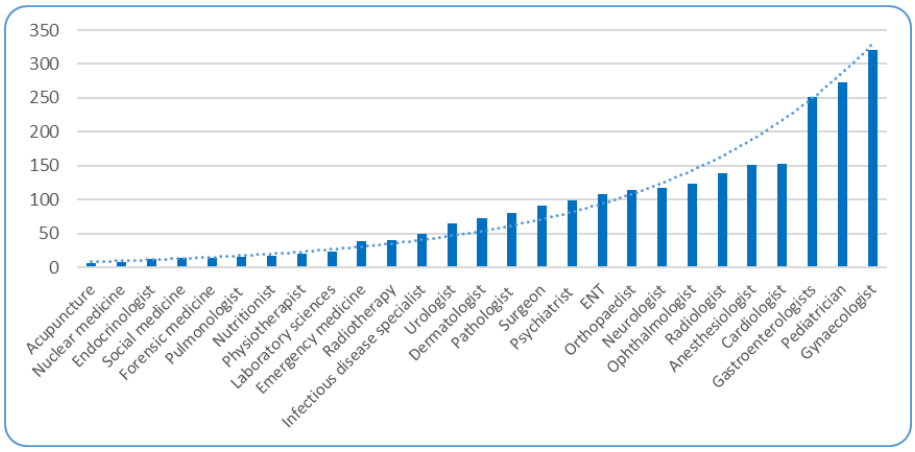

Figure 4. The frequency of specialist physicians' offices
Source: website of the Medical System Organization of Mashhad in 2020

3.2 Spatial diffusion of specialist physicians' offices

3.2.1 Investigating the diffusion pattern of specialist physicians' offices

In the discussion of spatial diffusion and distribution of services, identification of the diffusion origin is of particular importance. In the city of Mashhad, with the construction of Imam Reza and Ghaem hospitals in the years 1935 and 1961, adjacent to each other and around the Shariati Square, the first steps were taken to set up a specialized center for modern medicine. Specialist physicians' offices were gradually established near these two hospitals. Over time, this area absorbed more and more offices and became the main origin of such activities. Currently, a significant part of the specialist physicians' offices is located in this area of the city. The Standard Distance model shows this area as a circle with a radius of 2000 m (*Figure 5*).

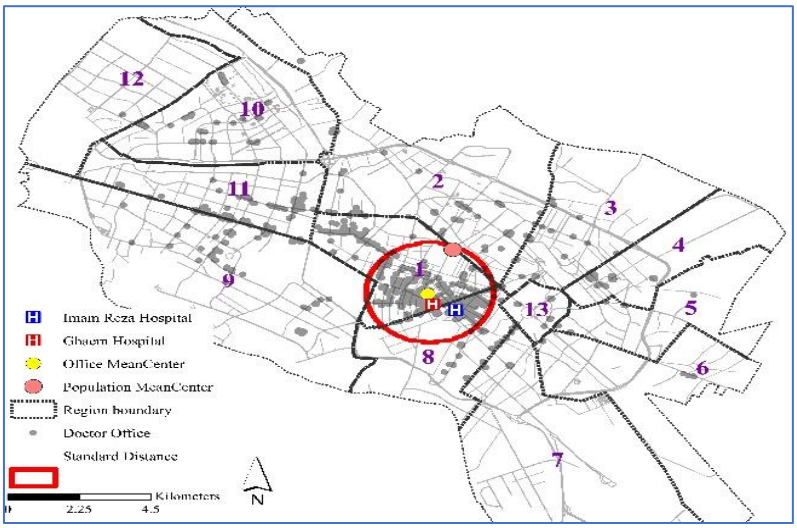

Figure 5. Mean center and diffusion zone of specialist physicians' offices in Mashhad

On the other hand, spatial autocorrelation and density profile models also show that at the origin of the offices, their density is high (as a hot spot) and leaving this area, there is not much difference among the areas of Mashhad. These maps indicate the high capability of the origin in attracting and accepting offices and not diffusing offices from the origin (*Figure 6*).

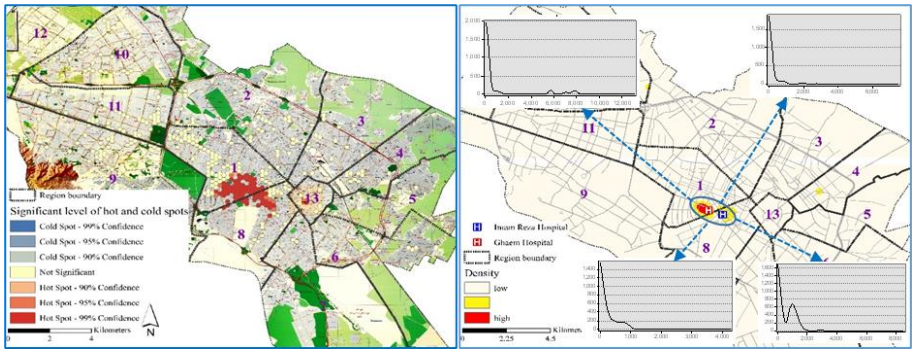

Figure 6. Hot and cold spots due to the diffusion of specialist physicians' offices in Mashhad (left) and the density diffusion pattern of specialist physicians' offices outside the central core of offices in the four main directions (right)

3.2.2 Investigating the deployment pattern of specialist physicians' offices in origin by the type of specialty

By using the Moran index for each specialty, it was revealed that the spatial pattern of all offices is a high-grade cluster type. In other words, homonymous specialties have attracted each other. Among the specialties, the maternity clinics with the Moran index of 0.48 have the highest value indicating their high-density deployment compared to other specialties. It is followed by radiology and gastroenterology specialties, respectively. In total, the average Moran index for all specialties is 0.3 and is significant at the level of 99% (*Figure 7*).

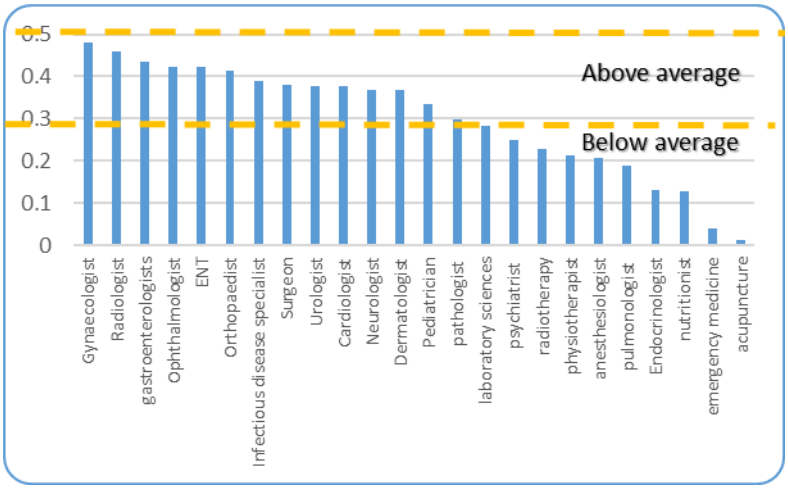

Figure 7. The amount of spatial autocorrelation between similar specialties by Moran index

According to the access threshold index, two types of actual and potential coverage levels can be identified. If the access threshold of a specialist physician is assumed to be 2000 m, then the current coverage level of the offices located at the diffusion origin, for some specialties, is up to 20% of

the area of Mashhad. However, their potential coverage level for many specialties is the entire area of the city. The results of using location-allocation models are shown in *Figure 8*.

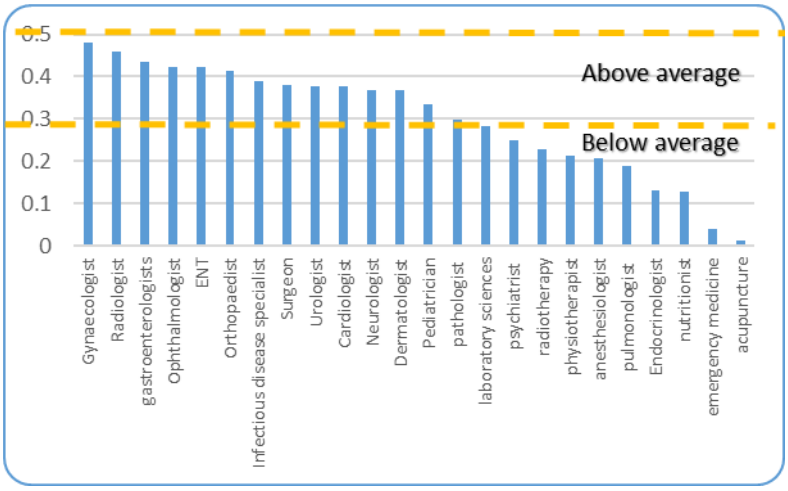

Figure 8. The diffusion gap of the offices between coverage current and coverage potential (to percent)

3.2.3 Spatial diffusion and its relationship with the number and coverage level of offices by the type of specialty in Mashhad

The final part of the status quo analysis responses the question that how the diffusion and coverage level of the offices change as they increase in number? To this end, correlation test and scatter diagrams were used.

The results indicate that there is a direct relationship between the number of offices in each specialty and the Moran coefficient value. In other words, as the number of offices in each specialty increases, the Moran index increases too suggesting an increase in the autocorrelation and clustering. The correlation coefficient value for these two variables is + 0.631 which is significant at the level of 99%. This is shown in Figure 8 in another way. It can be observed that as the number of offices in each specialty and consequently the Moran index increase, their spatial diffusion decreases and vice versa. For the lower number of offices, their spatial diffusion is in a better situation (*Figure 9* and *Table*).

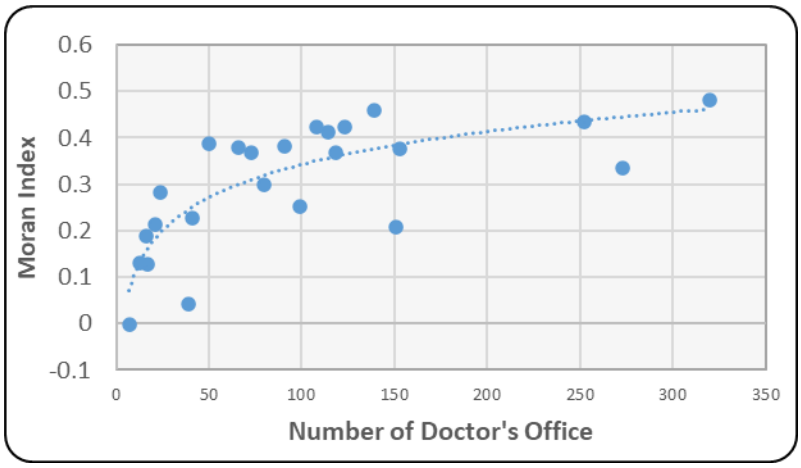

Figure 9. The relationship between the number of specialist physicians' offices and the Moran index value by the scatter diagrams in Mashhad

Table 1. Correlation coefficient between Moran index and the number of specialist doctors' offices in Mashhad

Correlation		Moran index	Number of offices
Moran index	Pearson Correlation	1	.631**
	Sig. (2-tailed)		.001
	N	24	24
Number of offices	Pearson Correlation	.631**	1
	Sig. (2-tailed)	.001	
	N	24	24

Note: ** means correlation is significant at the 0.01 level (2-tailed).

The coverage level of offices and its relationship with the number of offices may confirm the above issue. As the scatter diagram and the correlation coefficient showed, the higher the number of offices, the lower the average coverage level will be due to the strong functional overlap of the offices. The correlation coefficient value for this relationship is -0.661 (*Figure 10* and *Table 2*).

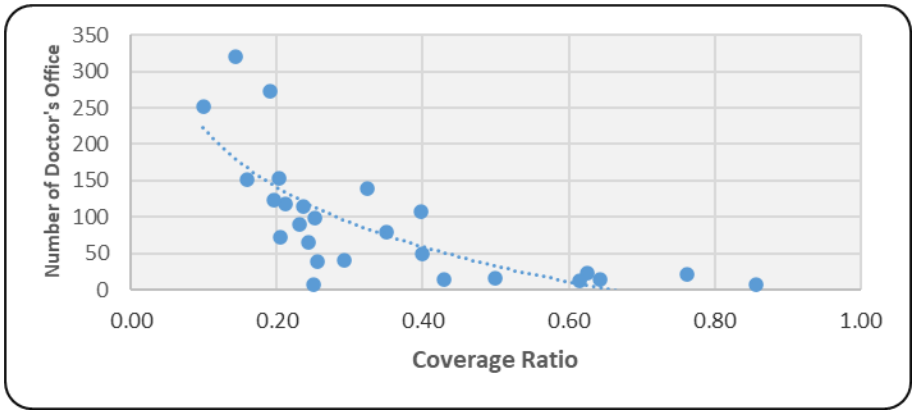

Figure 10. The relationship between the number of specialist physicians' offices and the functional coverage level of each office by the scatter diagram in Mashhad

Table 2 Correlation coefficient between the level of functional coverage and the number of specialist doctors' offices in Mashhad

	Correlation	Functional coverage level	Number of offices
Functional coverage level	Pearson Correlation	1	-.661**
	Sig. (2-tailed)		.000
	N	26	26
Number of offices	Pearson Correlation	-.661**	1
	Sig. (2-tailed)	.000	
	N	26	26

4. DISCUSSION

Despite the fact that almost 50 years have passed since the establishment of modern medicine in the city of Mashhad, the diffusion of these activities from the origin is very limited. However, in recent years, the number of offices in this area (origin) has increased by 448%. This may reject the hypothesis of stagnation at the origin and shows that the origin is still active.

Spatial autocorrelation models show the clustering pattern in this area, suggesting its high adsorption power. Contrary to other services in which competition involves spatial diffusion and redistribution, this is not the case with physicians' offices. In terms of the type of specialty, as the number of offices increases, the tendency to the origin increases and the diffusion decreases. This is assumed to be related to the presence of hospitals in this area but such a claim cannot be true because hospitals are widely distributed across 80% of the city area (versus 20% for offices). The reasons may be attributed to the psychological burden and presupposition of patients who have been seeking treatment in this area since long ago. So, this mental space has made the diffusion of these uses different from other ones.

The results indicate that the same number of offices covers 100% of the city area if some specialties are redistributed. So, spatial justice and equal access to such services has been challenged due to the lack of appropriate diffusion. The current pattern does not indicate the formation of treatment clusters in the city of Mashhad, because the offices are a small circle of this cluster, and the cluster formation doesn’t make sense without considering medical centers and hospitals.

If the non-diffusion of offices from the origin continues it can force the native population to leave this area and change it to a medical area. This increases the gap in access to such services between areas of Mashhad.

5. IMPLICATIONS AND RECOMMENDATIONS

5.1 Theorical implications

In general, the results indicate that as we are moving from the origin, the intensity of diffusion decreases, which is consistent with the results of (Comin, Dmitriev, and Ross, 2012; Caltabiano, Dreassi, Rocco, and Vignoli, 2019; Liefooghe, 2018; Miller, 2001; Fricks and Hanks, 2018; Lengyel and Jakobi, 2015) and inconsistent with the results of (Merriman, 2012). This means that distance is still a main factor in the distribution of phenomena. In terms of spatial diffusion pattern, expansion pattern can be seen in a very

limited manner in the study area. In other words, the current pattern shows the diffusion from the origin. This is in line with the results of (Lee, Lay, Chin, Chi, and Hsueh, 2014; Knoke, 1982; Thierry, Rizz, and Doignon, 2020; Yuming, 2004; Brown, Rounsevell, and Alexander, 2018) indicating spatial changes are considered in the analysis of changes in phenomena. However, in the study area the origin has absorbed more than diffused offices over time, so the spatial diffusion patterns cannot explain the spatial developments of the origin. The diffusion pattern in Mashhad has the following features. This could strengthen the global scientific record on space diffusion patterns:

1. In contrast to the common patterns of diffusion indicating the movement of phenomena from the origin to the surroundings, in the new pattern persistence in the origin and regeneration are observed. In the past patterns, this along with the spatial differences leads to a new aspect of the phenomenon evolution in the destination while in the new pattern, it causes spatial differences in the origin. So, the origin has the most mobility compared to other spatial diffusion patterns. Data streaming takes place at the origin and is limited spatially.

2. The new diffusion pattern reinforces specialization, polarization, and monocentric. It also increases its gap from the peripheral areas as it narrows the field for other activities. On the other hand, these activities can lead to a set of related uses to be formed and some other uses to be excluded. This may reduce the variety and mixing of land uses and separates the study area from other areas. The formation process of a new pattern is such that the emergence of a phenomenon in an area and its establishment over time leads to the establishment hub of the respective phenomenon to be formed so that there will be a significant difference between this area and other areas in terms of the presence of the phenomenon. If this will be continued the respective area serves as a magnet and attracts other similar spaces.

3. It seems that if the diffusion continues it will force the majority of population to leave the area. It may also cause similar activities with medical services to be absorbed so that this area will be isolated as a completely specialized area.

4. As the number of uses increase their functional area doesn't increase; however, their absorption power increases.

5. According to the abovementioned features, this pattern can be referred to as "Inverse Spatial Diffusion".

5.2 Practical recommendations

Given to their characteristics, individual spatial diffusion patterns can lead to a different type of spatial order. Therefore, these patterns should be identified by spatial analysis. Considering the inverse spatial pattern of physicians' offices in Mashhad, it is necessary to form and strengthen treatment clusters with the centrality of hospitals (given the 80% coverage level of hospitals in Mashhad). By strengthening the clusters, the redistribution of offices will be possible. For future research the spatial-temporal cube pattern can reveal more aspects of this issue.

AUTHOR CONTRIBUTIONS

Conceptualization, M.A.; methodology, M.A.; software, M.A.; investigation, M.A.; resources, M.A.; data curation, M.A.; writing—original draft preparation, M.A.; writing—review and editing, M.A.; supervision, M.A. All authors have read and agreed to the published version of the manuscript.

ETHICS DECLARATION

The authors declare that they have no conflicts of interest regarding the publication of the paper.

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